

MDC-G7789

FINAL REPORT: BIOMEDICAL APPLICATIONS IN SPACE  
PILOT PROGRAM IN THE SOUTHERN CALIFORNIA REGION



**MCDONNELL DOUGLAS**  
CORPORATION



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JANUARY 1979

MDC-G7789

Prepared by: *A. A. Kelton*

A. A. KELTON, Ph.D.  
Principal Staff Engineer  
Biotechnology Department

Approved by: *J. K. Jackson*

J. K. JACKSON  
Chief Technology Engineer - Biotechnology  
Vehicle, Energy and Biotechnology

NASA Contract No.: NAS9-15493

**MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST**

5301 Bolsa Avenue, Huntington Beach, CA 92647

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## 1.0 INTRODUCTION

The objective of this pilot program was to promote utilization of the Shuttle/Spacelab for medical and biological research applied to terrestrial needs. The program was limited to the Southern California region and consisted of the following five tasks:

- 1) Preparation of Educational Materials;
- 2) Identification of Principal Investigators;
- 3) Initial Contact and Visit;
- 4) Development of Promising Applications; and
- 5) Evaluation of Regional Program Methodology.

In tasks 2 and 3, alternative approaches were explored so that different methodologies could be evaluated in Task 5. The remainder of this report presents the results for each of the five major tasks and discusses the major findings of the study.

## 2.0 RESULTS

### 2.1 Preparation of Educational Materials

Materials were prepared for presentation to potential principal investigators. The materials covered the following three areas:

- 1) Review of past biomedical findings for spaceflight with emphasis on potential applications of the space environment for ongoing biomedical research;
- 2) Overview of Shuttle/Spacelab with emphasis on description of potential research environment, scenario, facilities and limitations;
- 3) Process for submitting research proposals to NASA with emphasis on responding to the Announcement of Opportunity with a Letter of Intent and a proposal.

The materials that were prepared are shown in Appendix I. The materials were prepared in a format that was used in viewgraphs for a large audience or in flipcharts for presentation to 1-3 persons. In addition, the NASA film, "Biomedical Applications in Space" was presented to all large audiences.

The presentation materials were derived from several publications and sources which are shown in Tables I-III. Sources on past and potential applications of the space environment are given in Table I. The overview of Shuttle/Spacelab was summarized from the sources listed in Table II. The objective of the overview was to introduce the potential P.I. to the Space Shuttle system and its mission profile, and illustrate the flow of a typical life science experiment through integration, flight, data handling, recovery of specimens, etc. Table III shows the sources used to summarize the process for submitting research proposals to NASA. The materials were modeled after the presentation "Announcement of Flight Opportunity Process" given by Dr. John Rummel at the first "Biomedical Applications in Space" meeting.

## 2.2 Identification of Principal Investigators

Three approaches were used to identify PI's in the Southern California region:

- 1) points of contact;
- 2) science network method; and
- 3) areas of research (literature search)

The use of these approaches permitted comparison of different methodologies.

Points of contact, such as department chairman and research directors, were established at major research centers for assistance in locating PI's or research projects that might benefit from the space environment. Institutions were emphasized that had programs in medical or applied biological sciences. A number of private firms were also contacted. A list of the research centers which were contacted and the results of the contact are shown in Table IV. Table V lists some of the proposed ideas for research in 0-g, while Table VI gives the author's opinion regarding which of the proposed ideas may be the most promising.

TABLE I  
INFORMATION RESOURCES ON BIOMEDICAL RESEARCH IN SPACE

1. Space, A Resource for Earth, An AIAA review edited by J. Grey, P. Downe and B. Davis, AIAA, N. Y., April 1977.
2. Life Sciences in the Shuttle Era, February 1975, preliminary, prepared by the NASA Life Sciences Directorate.
3. Life Sciences Guideline Data for Long-Duration Missions, April 1977, preliminary, W. E. Hull, Ph.D., Chairman.
4. John A. Mason, Opportunities for Biological Research in Space During the 1980's, Bioscience, Vol. 26, pp. 325-329, May 1976.
5. Experiments of Biosatellite II, J. F. Saunders (Ed.), National Aeronautics and Space Administration, 1971, NASA SP-204.
6. Foundations of Space Biology and Medicine - Joint USA/USSR Publication Three Volumes, M. Calvin and O. G. Gazenko (Co-chairmen), Scientific and Technical Information Office, National Aeronautics and Space Administration, Washington, D. C., 1975.
7. Human Factors in Long-Duration Spaceflight, Space Science Board, National Research Council (Eds.), National Academy of Sciences, Washington, D. C., 1972.
8. Physiology in the Space Environment, Space Science Board, National Research Council (Eds.), National Academy of Sciences, Washington, D. C., 1968, Vol. I (Circulation), NAS-NRC 1485A, and Vol. II (Respiration), NAS-NRC 1485B.

TABLE I (continued)  
INFORMATION RESOURCES ON BIOMEDICAL RESEARCH IN SPACE

9. The Proceedings of the Skylab Life Sciences Symposium, Life Sciences Editorial Board, Lyndon B. Johnson Space Center, Houston, Texas, Vol. I and II, November, 1974, NASA TM X-58154.
10. Pulliam, Jean E., Bibliography of Biosatellite Research, Biological Sciences Communication Project, George Washington University Medical Center, Washington, D. C., 1970, NASA NSR 09 010 027.
11. Scientific Users of the Space Shuttle, Space Science Board, National Research Council (Eds.), National Academy of Sciences, Washington, D. C., 1974.
12. Young, R. S., Biological Experiments in Space, Space Science Reviews 8, D. Reidel Publishing Co., Dordrecht-Holland, 1968, 665-689.
13. Johnston, R. S., Dietlein, L. F., and Berry, C. A. (Eds.), Biomedical Results of APOLLO, 1975, National Aeronautics and Space Administration, Washington, D. C., NASA SP-368.
14. Parker, J. F. and West, V. R. (Eds.), Bioastronautics Data Book, National Aeronautics and Space Administration, Washington, D. C., 1973, NASA SP-
15. Johnston, R. S., and Dietlein, L. F. (Eds.), Biomedical Results from Skylab, 1977, National Aeronautics and Space Administration, Washington, D. C., NASA SP-377.
16. Nicogossian, A. E., The Apollo-Soyuz Test Project - Medical Report, 1977, National Aeronautics and Space Administration, Washington, D. C., NASA SI

Table II  
INFORMATION RESOURCES ON SHUTTLE/SPACELAB

1. Space Transportation System, User Handbook, NASA-JSC, June 1977.
2. Life Sciences Guide to the Space Shuttle and Spacelab (sent to proposers who submit a notice of Intent to Propose and potential investigators who formally request a copy)
3. Announcement of Opportunity: Life Sciences Investigations on Space Shuttle/Spacelab Missions, 1981 through 1982, AO No. OSS-1-78, February 7, 1978, summary overview of Shuttle/Spacelab.
4. Spacelab Users Guide, NASA & ESA, GPO 0-231-154, November 1976.
5. Space Shuttle, prepared by Lyndon B. Johnson Space Center, NASA SP-407, 14 January 1976.
6. Life Sciences Experimenters Handbook, April 1977, MDAC G6780.



TABLE III  
INFORMATION RESOURCES ON SUBMITTING  
BIOMEDICAL RESEARCH PROPOSALS TO NASA

1. Announcement of Opportunity: Life Sciences Investigations on Space Shuttle/Spacelab Missions 1981 through 1982, AO No. OSS-1-78, February 7, 1978.
2. Guide to Preparation of Life Sciences Flight Experiment Proposals, March 1978, National Aeronautics and Space Administration, Washington, D. C.
3. Life Sciences Experimenters Handbook, April 1977, MDAC G6780.
4. John A. Mason, Opportunities for Biomedical Research in Space During the 1980's, Bioscience, Vol. 26, pp. 325-329, May 1976.

TABLE IV - LIST OF RESEARCH CENTERS CONTACTED

<u>ORGANIZATIONS/COMPANIES CONTACTED</u>	<u>INDIVIDUAL CONTACTED</u>	<u>INITIAL RESPONSE/MEETING RESULT</u>
UCLA DEPT. OF BACTERIOLOGY	DR. RITTENBURG	NO APPLICATIONS
UCLA DEPT. OF BIOLOGICAL CHEMISTRY	DR. EMIL SMITH	NO APPLICATIONS
UCLA DEPT. OF BIOLOGY	DR. MUSCATINE	UNDER CONSIDERATION
UCLA DEPT. OF MICROBIOLOGY AND IMMUNOLOGY	DR. JOHN FAHEY DEFERRED TO DR. BONIVIDA	3-9-78. NINE SCIENTISTS IN ATTENDANCE. VERY INTERESTED, EXPERIMENT UNDER CON- SIDERATION. EXPERIMENT LIKELY FROM DR. CELSA SPINA. CONFERENCE WITH DR. FAHEY.
UCLA DEPT. OF NEUROSCIENCE	DR. SAMUEL EIDUSON	UNDER CONSIDERATION
UCLA DEPT. OF PHYSIOLOGY	DR. WILFRIED MOMMAERTS	2-21-78. THREE SCIENTISTS IN DISCUSSION GROUP. VERY INTERESTED, EXPERIMENT UNDER CONSIDERATION.
UCLA DEPT. OF RADIOLOGY	DR. AMOS NORMAN	3-14-78. TWENTY-FIVE SCIENTISTS IN ATTEN- DANCE. SIX WERE VERY INTERESTED. TWO EXPERIMENTS UNDER CONSIDERATION.
UCI DEPT. OF DEVELOPMENTAL AND CELL BIOLOGY	DR. MICHAEL BURNS	3-6-78. FIVE SCIENTISTS IN ATTENDANCE. GROUP EXPERIMENT UNDER CONSIDERATION. EXPERIMENT ANTICIPATED FROM DR. DONALDSON.
UCI DEPTS. OF MOLECULAR BIOLOGY AND BIOCHEMISTRY	DR. ROLAND DAVIS	NO APPLICATIONS. NOTE: DR. DONALDSON ATTENDED MEETING WITH DR. BURNS.
UCI DEPT. OF MEDICAL MICROBIOLOGY	DR. PAUL SYPHERD	3-1-78. FIVE SCIENTISTS IN ATTENDANCE. DR. GEORGE GUTMAN HAS EXPERIMENT UNDER CONSIDERATION.
UCI DEPT. OF PHYSIOLOGY	DR. KENNETH BALDWIN	2-28-78. THREE SCIENTISTS IN DISCUSSION GROUP. VERY INTERESTED, EXPERIMENT ANTICIPATED.
UCI DEPT. OF PSYCHOBIOLOGY	DR. RICHARD THOMPSON	NO APPLICATIONS.

TABLE IV (continued)

<u>ORGANIZATIONS/COMPANIES CONTACTED</u>	<u>INDIVIDUAL CONTACTED</u>	<u>INITIAL RESPONSE/MEETING RESULT</u>
UCI DEPT. OF ENVIRONMENTAL HEALTH AND PUBLIC MEDICINE	DR. TIMOTHY CROCKER	NO APPLICATIONS
UCI DEPT. OF RADIOLOGY	DR. ERIC MILNE	3-1-78. VERY INTERESTED, EXPERIMENT LIKELY.
UCI DEPT. OF HEMATOLOGY AND ONCOLOGY	DR. STEPHEN ARMENTROUT	3-13-78. THREE SCIENTISTS IN DISCUSSION GROUP, UP TO FOUR EXPERIMENTS ANTICIPATED.
USC DEPT. OF PHYSIOLOGY	DR. JAMES HENRY	1-11-78. DR. DENIS MITCHELL, VERY INTERESTED, EXPERIMENT ANTICIPATED.
USC DEPT. OF BIOLOGY	DR. BERNARD ABBOTT DEFERRED TO DR. BERNARD STRELER	ALREADY INVOLVED IN NASA RESEARCH, NO APPLICATIONS
USC DEPT. OF CELLULAR AND MOLECULAR BIOLOGY	DR. KARMEN	NO APPLICATIONS
USC DEPT. OF PHARMACOLOGY	DR. DAVID BERMAN	NO APPLICATIONS
USC DEPT. OF BIOMEDICAL ENGINEERING	DR. FRED GRODINS	UNDER CONSIDERATION
USC DEPT. OF MICROBIOLOGY	DR. IRVING GORDON	UNDER CONSIDERATION
USC DEPT. OF EXPERIMENTAL PATHOLOGY	DR. NANCY WARNER	NO APPLICATIONS
LOMA LINDA MEDICAL SCHOOL DEPT. OF MICROBIOLOGY	DR. CHARLES WINTER DR. ROBERT NUTTER	3-2-78. TWENTY-SEVEN SCIENTISTS IN ATTENDANCE, FOUR INDICATIONS OF INTEREST. MAY REQUIRE ADDITIONAL MEETINGS.
CITY OF HOPE, DEPT. OF CYTOGENETICS AND CYTOLOGY	DR. RAYMOND TEPLITZ	2-23-78. ELEVEN SCIENTISTS IN ATTENDANCE, TWO INDICATIONS OF INTEREST.
CITY OF HOPE, DEPT. OF BIOLOGY	DR. ROBERT SEECOF	3-2-78. THREE SCIENTISTS IN ATTENDANCE, EXPERIMENT ANTICIPATED.
CALIFORNIA INSTITUTE OF TECHNOLOGY	DR. LEE HOOD DR. NORMAL HUROWITZ	ALREADY KNOWLEDGEABLE THROUGH JPL.

TABLE IV (continued)

<u>ORGANIZATIONS/COMPANIES CONTACTED</u>	<u>INDIVIDUAL CONTACTED</u>	<u>INITIAL RESPONSE/MEETING RESULT</u>
HANCOCK RESEARCH	DAVID MYERS	3-7-78. TEN SCIENTISTS IN ATTENDANCE. VERY INTERESTED, EXPERIMENT UNDER CONSIDERATION.
ABBOTT SCIENTIFIC PRODUCTS DIV.	DR. CHARLES ALLAIN DR. ROSS ROBINSON	NO INTEREST
BENTLY LABORATORIES	DR. FRED THIEDE	NO APPLICATIONS.
INTERNATIONAL CHEMICAL & NUCLEAR FLOW LABORATORIES	DR. RON COOK	BIOMEDICAL RESEARCH DISCONTINUED.  3-6-78. VERY INTERESTED. UP TO FOUR EXPERIMENTS ANTICIPATED, THREE EXPERIMENTS ON SPACE PRODUCTIVITY.
BIONETICS	MR. PAIK	ALREADY KNOWLEDGEABLE, SUPPORT CONTRACTOR FOR NASA-AMES.
HYLAND LABORATORIES	DR. KAMERON MAXWELL	UNDER CONSIDERATION.
JOHN DREW MEDICAL SCHOOL AND MARTIN LUTHER KING HOSPITAL	DR. N. VENKATESAN, DR. LAWRENCE W. ALFRED, & DR. ANTHONY GIORGIO	4-13-78. APPROXIMATELY 60-80 SCIENTISTS IN ATTENDANCE. THREE INDICATIONS FOR LETTER OF INTENT, ONE SCIENTIST STATED INTENTION TO SUBMIT PROPOSAL.

TABLE V - LIST OF PROPOSED EXPERIMENTS, IDEAS OR GOALS, AND CHIEF CONTACT

- A) DR. KENNETH BALDWIN, UCI DEPARTMENT OF PHYSIOLOGY  
ROLE OF GRAVITY IN DEVELOPMENT OF FINE STRUCTURE AND SUBCELLULAR STRUCTURE OF MUSCLE.
- B) DR. ERIC MILNE, UCI DEPARTMENT OF RADIOLOGY  
QUANTITATION OF LUNG CAPILLARY RESPONSE AND LUNG FLUID DISTRIBUTION IN ZERO-GRAVITY.
- C) DR. DENIS MITCHELL, USC DEPARTMENT OF PHYSIOLOGY  
ISOLATION OF OTILITH, SEMICIRCULAR CANAL, AND NEUROLOGICAL RESPONSES OF RATS TO MOTION SICKNESS  
AND DRUG SENSITIVITY MEASURED BY INDUCTION OF PICA IN ZERO-GRAVITY.
- D) DR. ROBERT SEECOF, CITY OF HOPE, DEPARTMENT OF BIOLOGY  
THE EFFECT OF GRAVITY ON THE IN VITRO, RAPID ASSOCIATION, DIFFERENTIATION AND DEVELOPMENT OF  
NEUROLOGICAL AND MUSCULAR TISSUE OF DROSOPHILA.
- E) DR. GEORGE GUTMAN, UCI DEPARTMENT OF MEDICAL MICROBIOLOGY  
THE EFFECT OF ZERO-GRAVITY ON THE REGULATION OF LYMPHOID COMPARTMENTS
- F) DR. WILFRIED MOMMAERTS, UCLA DEPARTMENT OF PHYSIOLOGY  
THE EFFECT OF ZERO-GRAVITY ON THE NEUROLOGIC REGULATION OF MUSCLE TONE IN RELATION TO MUSCULAR  
DYSTROPHY.

TABLE V (continued)  
LIST OF PROPOSED EXPERIMENTS, IDEAS OR GOALS, AND CHIEF CONTACT (CONTINUED)

- G) DR. RON C. COOKE, FLOW LABORATORIES
- 1) ENHANCEMENT OF PROTOPLAST FUSION FOR PRODUCTION OF NEW TYPES OF SUPERPLANTS.
  - 2) MASS SUSPENSION CULTURE OF PLANT CELLS FOR PRODUCTION OF SECONDARY PRODUCTS, E.G., ALKALOIDS, FOR CANCER RESEARCH.
  - 3) MASS SUSPENSION CULTURE OF SUPERPLANT CLONES.
  - 4) GRAVITY DEPENDENCE OF POLARITY INDUCTION OF PLANT EMBRYOGENESIS.
- H) DR. LYNN DONALDSON, UCI DEPARTMENT OF PSYCHOBIOLOGY  
THE EFFECT OF ZERO-GRAVITY ON NEUROMUSCULAR COORDINATION (MUSCLE ACTIVITY) IN ADAPTATION USING AN ARTHROPOD MODEL SYSTEM.
- I) DR. STEPHEN ARMENTROUT, UCI DEPARTMENT OF HEMATOLOGY AND ONCOLOGY
- 1) WHOLE BLOOD VISCOSITY AT NORMAL AND NORMAL VARIATIONS OF pH.
  - 2) HEMORHEOLOGY OF RED BLOOD CELLS IN ZERO-GRAVITY.
- J) DR. HERMAN BRANSON, UCI DEPARTMENT OF HEMATOLOGY AND ONCOLOGY  
PERIPHERAL MECHANISMS FOR PLATLET FUNCTION DURING CEPHALAD FLUID SHIFT
- K) DR. LEWIS SLATER, UCI DEPARTMENT OF HEMATOLOGY AND ONCOLOGY AND DEPARTMENT OF MEDICINE  
QUANTITATION OF T- AND B-CELL SUBPOPULATIONS DURING ADJUSTMENT TO ZERO-GRAVITY.
- L) DR. GARTH NICOLSON, UCI DEPARTMENT OF MOLECULAR AND CELL BIOLOGY  
DIFFERENTIAL HOMING ABILITY OF CLONED MALIGNANT CELLS IN MOUSE MELANOMA.

TABLE VI - WHICH EXPERIMENTS ARE THE MOST PROMISING?

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1. PLANT CELLS AND PLANT EMBRYOGENESIS (DR. RON COOKE).
  2. ALTERNATE PATHWAYS OF MUSCLE DEVELOPMENT (DR. KENNETH BALDWIN).
  3. PERIPHERAL MECHANISMS IN THE CONTROL OF PLATLET FUNCTION (DR. HERMAN BRANSON).
  4. BLOOD VISCOSITY AND RBC HEMORHEOLOGY (DR. STEPHEN ARMENTROUT).
  5. QUANTITATION OF LUNG VESSEL RESPONSE AND LUNG FLUID DISTRIBUTION (DR. ERIC MILNE)
  6. NEUROMUSCULAR COORDINATION STUDIES (DR. LYNN DONALDSON).
- 
7. ISOLATION OF OTILITH, SEMICIRCULAR CANAL AND NEUROLOGICAL COMPONENTS IN MOTION SICKNESS AND DRUG SENSITIVITY (DR. DENIS MITCHELL).
  8. EFFECT OF ZERO-G ON NEUROLOGIC REGULATION OF MUSCLE TONE IN RELATION TO MD (DR. WILFRIED MOMMAERTS).
- 
9. DIFFERENTIAL HOMING ABILITY OF CLONED MALIGNANT CELLS (DR. GARTH NICOLSON).
  10. EFFECT OF ZERO-G ON REGULATION OF LYMPHOID COMPARTMENTS (DR. GEORGE GUTMAN).
  11. QUANTITATION OF T- AND B-CELL SUBPOPULATIONS DURING ADJUSTMENT TO ZERO-G (DR. LEWIS SLATER).

According to the Science Network Method developed by John Mason, scientists associated with a particular area of research that might benefit from applications of the space environment were asked to identify peer investigators and promising, young, less prominent researchers in their laboratories or institutions. Prominent investigators were contacted by telephone and given a day or so to consider such a list of peer investigators. Individuals from the initial list were then contacted and asked for a similar list. This list was not limited to individuals in the Southern California region. The process continued until a network of investigators was established in a particular area of research. This method was particularly efficient, but limited to research areas of known potential.

Science networks were established in the following areas of research:

- 1) regulation of metabolic systems for skeletal and heart muscle
- 2) blood rheology;
- 3) cardiopulmonary mechanics and extravascular lung water;
- 4) enhancement of protoplast fusion.

A science network is illustrated in Figure 1. The names, addresses and phone numbers of the scientists in each of the above science networks are tabulated in Appendix II.

Techniques of literature searching were also used to attempt to identify potential PI's. Index Medicus and Biological Abstracts were surveyed for areas of research that are especially promising for application of O-g, e.g., bone demineralization, fluid shifts and water balance, orthostatic tolerance, vestibular function, muscle atrophy, cardiovascular dynamics, renal hemodynamics, etc. The search sought to identify ongoing research on disease processes that might be better understood by utilization of the space environment. By use of the American Men and Women of Science, attempts were made to identify active PI's in the Southern California area. However, after 40 hours of searching, almost no useful information was obtained. It was very evident that the point of contact and science network methods were much more productive, efficient, and meaningful than the literature search method. Therefore, literature searching was discontinued.



RECOMMENDED SCIENTISTS

ORIGINAL PAGE IS  
OF POOR QUALITY

RECOMMENDING SCIENTISTS

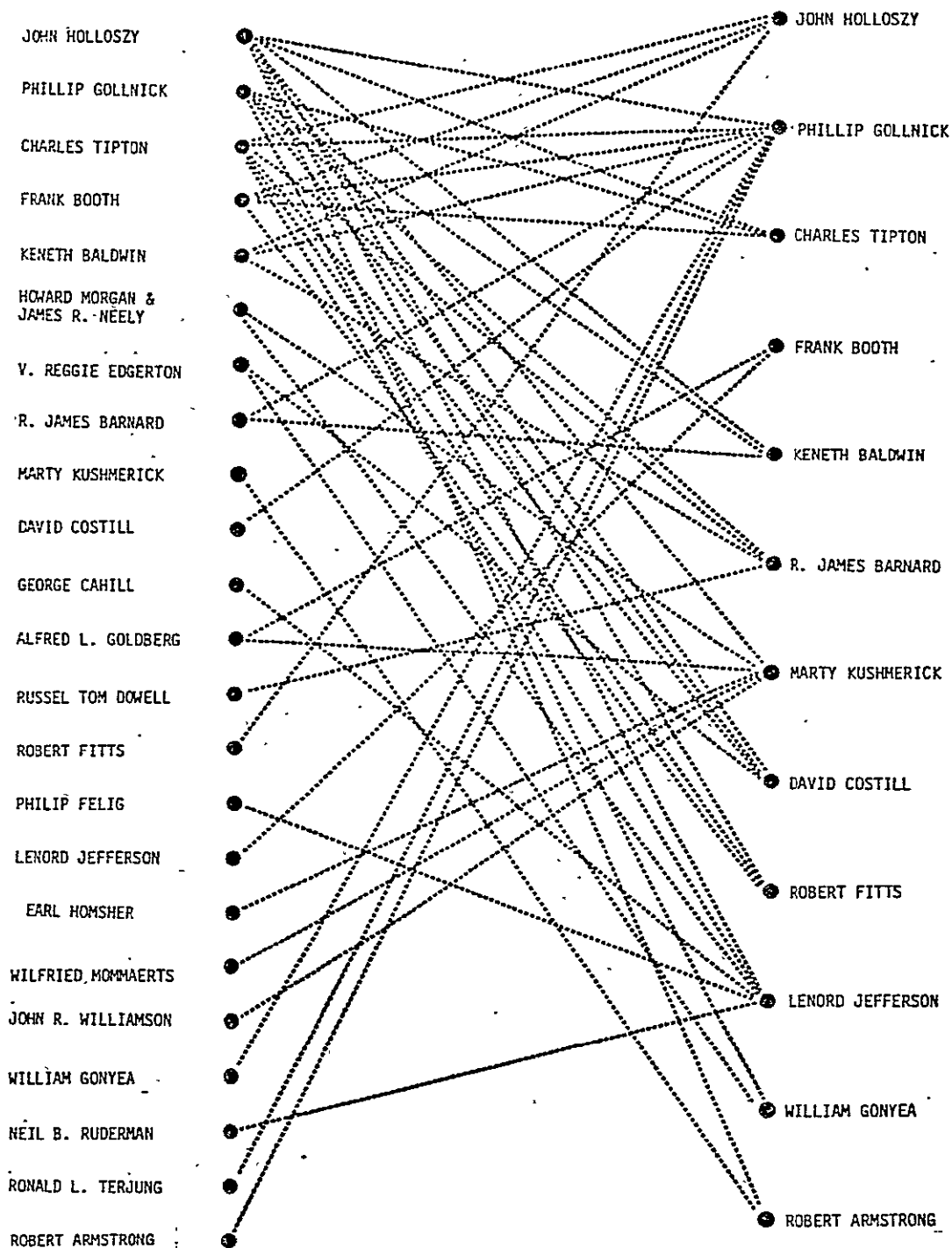


FIGURE 1 - SCIENCE NETWORK FOR REGULATION OF METABOLIC SYSTEMS  
FOR SKELETAL AND HEART MUSCLE

### 2.3 Initial Contact and Visit

Following the initial identification of potential PI's and preliminary contacts of institutions, individuals were telephoned and visits were arranged for presentation of the educational materials. Arrangements were made for one of three types of presentation:

- 1) formal seminar groups;
- 2) informal discussion group; or
- 3) a particular scientist and his research staff

As arranged, presentation to formal seminar groups took place during regularly scheduled departmental seminars. No special arrangements other than scheduling were required. Altogether, five presentations were made at regularly scheduled seminars. Total attendance was about 102 scientists. Following presentation, the attendees were polled to identify those investigators who had a strong interest in space research. Of the total, twelve scientists expressed an interest in space research and three stated an intent to propose an experiment.

The informal discussion group was scheduled with smaller groups who had a known interest in space research. Although the presentations were occasionally part of regular seminars in a department, the meetings were more often especially scheduled. The chairman of the meeting contacted department members and invited those who expressed an interest in opportunities for research in space. These scientists were asked to consider potential applications of the space environment to their ongoing research. Usually, the presentation was shortened and tailored to the interests of the group. During the meeting, the attendees were asked to discuss their research programs and ideas for space research. Potential PI's were identified for possible follow-up discussions. Presentations were made to seven discussion groups for a total of 33 scientists. There were 13 indications of intent to propose. Four were involved in follow-up discussions and meetings leading to 4 known proposals.

Presentations were made to individual investigators on three occasions. The presentation was informal and tailored to the interests and needs of the individual. These individuals had no previous experience with the space program, but were known to do research in areas that could benefit from the space environment. All submitted letters of intent to propose. Dr. Ron Cook submitted four letters. This and our past experience indicates that the one-to-one discussion is more productive of research concepts than group presentations.

#### 2.4 Development of Promising Applications

Interested investigators were followed-up and visited, as necessary, to coordinate and encourage the development of research concepts and the translation of those concepts into proposals to NASA.

Follow-up contacts to encourage development of research concepts and to monitor progress were mostly by telephone. Three follow-up visits were made to potential PI's, but these were found to be no more productive than telephone discussions. During each of the follow-up contacts, problems and solutions encountered in the development of concepts and their translation into proposals were identified. These problems tended to be within the following four major categories which are discussed in subsequent paragraphs:

- 1) lack of knowledge about results of past biomedical research in space;
- 2) organizing the proposed research in line with the NASA experiment development program;
- 3) establishing a clear relationship between experiment objectives and the unique characteristics of the space environment; and
- 4) lack of provisions for young investigators.

Probably the most frequent and serious problem was that scientists were not familiar with the research accomplishments of previous spaceflights in their special area of research. As a result, many did not consider submitting proposals because:

- 1) they did not wish to expend the time to propose an idea already accomplished or already proposed by other investigators, and
- 2) they believed that new research should be a logical extension of past research.

In many cases, we were able to provide the required information from our personal libraries. In particular, the NASA publications "Biomedical Results from Skylab," "Biomedical Results of Apollo," and "The Apollo-Soyuz Test Project - Medical Report," were extremely useful. The document "BIOSPEX, A summary of Life Science Experiments Carried on U. S. Spacecraft" was found to be an outstanding resource, but, unfortunately, was too late in publication for use in responding to the current AO (February 7, 1978). The NASA newsletter "Life Science Status Report" could also provide up-to-date information and reviews of past accomplishments and future plans in each area of research in the life sciences. However, the information must reach the segment of the scientific community that is interested in utilizing the space environment. Identification of this group may be the most important product of these pilot programs.

The second problem encountered was in organization of the research proposal. Frequently, the scientists did not specify or separately price the work to be done in the experiment development phase. Whenever this problem was identified, we suggested corrective measures. However, in three of six follow-ups during June the proposal had already been sent to NASA.

In three of five proposals that we have had an opportunity to read, a relationship between experiment objectives and the unique characteristics of the space environment had not been clearly established. We also noted this problem during presentations to investigators. Although the requirement for utilization of the space environment was clearly stated in the AO and during our presentations, many investigators did not derive a hypothesis from fundamentals. More frequently, it was suggested that a "try and find out" experiment might be done. In such cases, an education on the fundamental effects of the space flight environment, e.g., zero-gravity and an in-depth understanding of previous biomedical research in space is required.

Although we encountered considerable enthusiasm among young investigators as well as a desire to be part of the NASA program, they were reluctant to submit proposals. First, they held postdoctoral or temporary positions and could not depend upon their current institution for support during the entire term of the experiment. Second, they did not have experience in implementing a program of the magnitude and complexity required for research in space. The AO was specific in requiring commitment and support from the investigator's institution and demonstrated competence of the investigator. Despite our suggestions that the research contract could be transferred to a different institution at a later time, the young investigators, in general, did not respond beyond the letter of intent.

### 3.0 DISCUSSION AND RECOMMENDATIONS

The pilot program met its objectives. Information was provided to the scientific community at meetings and seminars throughout the southern California region. Discussions with scientists revealed promising applications of the space environment which led to letters of intent to NASA and subsequent proposals. Different methods for identification of principal investigators and for presentation of materials were evaluated.

Of the different approaches used to identify principal investigators, the "points of contact" method and the "science network" method were found to be the most useful and were complimentary. The "points of contact" method utilized the contacts and knowledge of research directors at private research centers and appropriate department chairmen at universities. This method was found to be useful in determining general interest in the Shuttle/SpaceLab program in the southern California region. However, once a particular research area had been identified as promising, the "science network" method was found to be the most efficient for identification of interested scientists. Scientists who were pursuing a particular area of research were found to be very knowledgeable about names and institutions of other scientists doing research in the same or closely related area. Seldom were these scientists within the same department or institution, so that the science network was nationwide and even international in scope.

Of the three types of presentations, the most productive meetings were with smaller groups. Indeed, the one-to-one discussion was more productive of research concepts than any of the group presentations. Interested scientists in the large groups were not easily identified. Also, the discussions were more superficial and the ideas put forth were more general in large groups than in small groups.

A few general observations were also made during the pilot program. Most important, scientists were not familiar with the past life sciences research accomplishments of NASA. This lack of background not only affects the quality of scientific proposals, but also influences whether a scientist will consider submitting a proposal. During discussions following the presentation, several scientists openly expressed enthusiastic support for the space program. Obviously, there is a need for lines of communication between NASA and the life sciences community. That segment of the scientific community that enthusiastically supports the NASA programs should be heard by appropriate government officials. Further, NASA should continue to identify interested scientists and inform them on details of past accomplishments, future plans, and opportunities for participation. Usually, such activities are conducted through a formal scientific association.

As a result of this pilot study, the following recommendations are put forth:

- 1) NASA should continue to identify interested scientists and inform them of opportunities for research in space.
- 2) NASA should greatly expand efforts to inform the scientific community with a detailed account of past accomplishments in life sciences research and opportunities for future research. As an example, the newsletter "Life Sciences Status Report" might include review articles on each major area of research with information on how to obtain copies of original articles and reports.
- 3) Efforts should continue to gather together groups of interested scientists to develop concepts for biomedical application of space research. Formation of a formal scientific association should be considered. An association would sustain scientific interest beyond the initial NASA investment.

- 4) A "science network" should be established for each promising application of biomedical research in space.
- 5) Provisions should be made in the "Announcement of Opportunity" for participation of young investigators. For example, review and selection of proposals from young investigators might be the basis of postdoctoral, etc., awards at NASA centers where the experiments could be developed for spaceflight.

The enthusiasm and momentum generated by this and other pilot programs must be maintained and converted into viable programs for biomedical applications in space and into an identifiable and involved scientific community.

APPENDIX I - SOME OF THE MATERIALS USED  
IN A PRESENTATION ENTITLED  
"BIOMEDICAL APPLICATIONS IN SPACE"

The following materials were used in a viewgraph presentation at seminars. In addition, the NASA film "Biological Applications in Space" was shown. For presentations to individual scientists, appropriate materials were selected and presented in a handout and flipchart format.



## UNIQUE CHARACTERISTICS OF THE SPACELAB ENVIRONMENT

- SUSTAINED WEIGHTLESSNESS
- ISOLATION FROM EARTH/LUNAR PERIODICITIES
- COSMIC RADIATION
- NEAR VACUUM
- DIRECT SOLAR ILLUMINATION

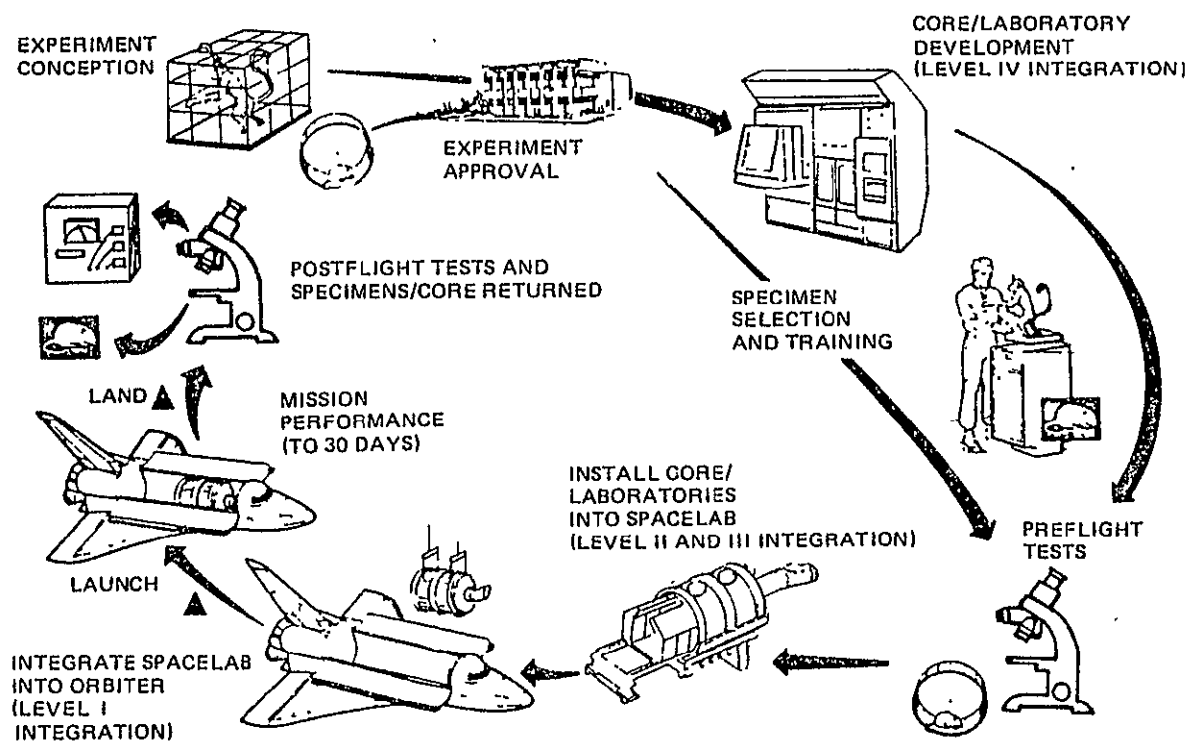
## EXPERIMENT PLANNING

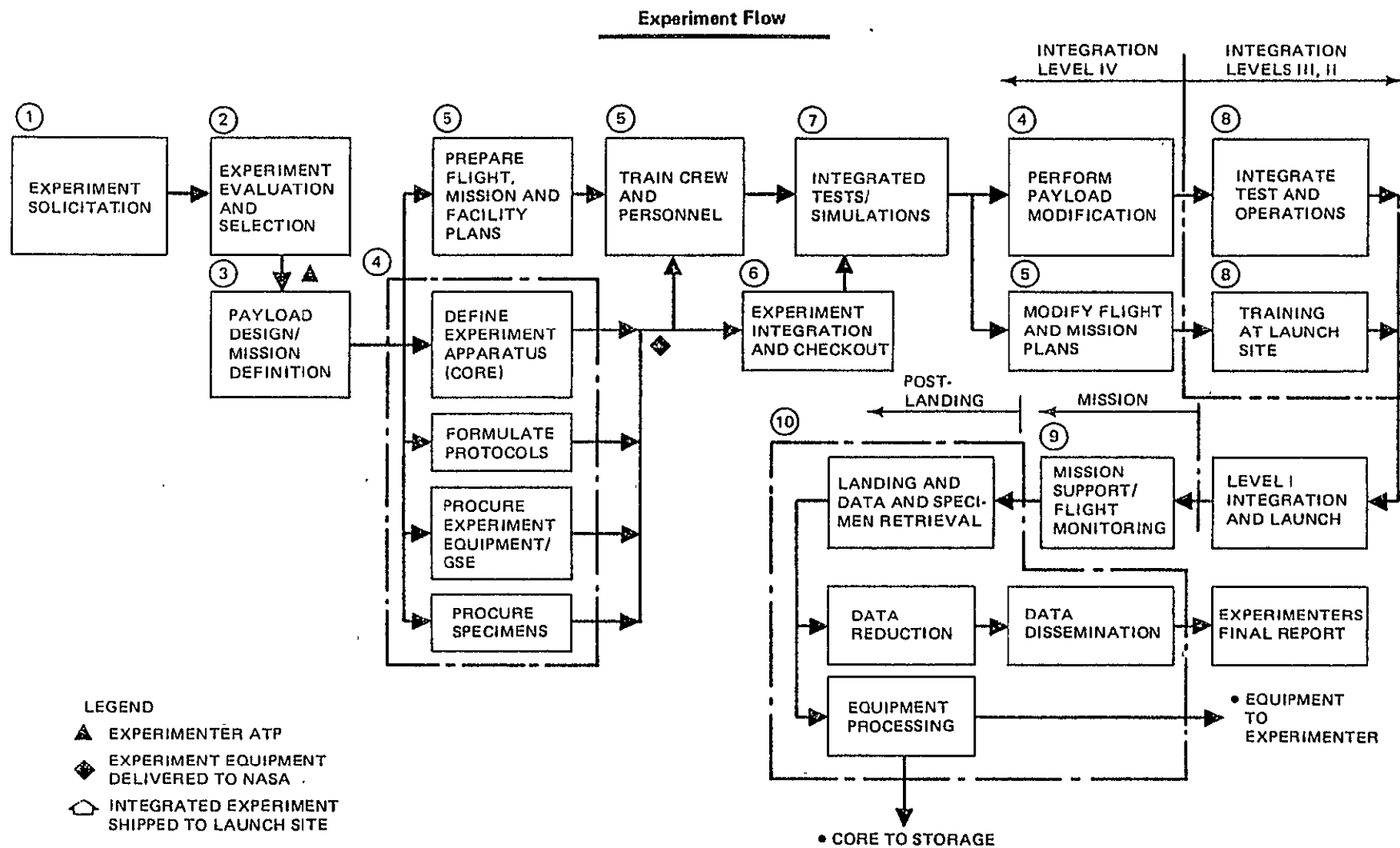
- They should address basic life sciences research.
- There should be well substantiated reasons to expect space flight to produce effects different from those found on earth.
- Results of the experiment should relate directly to recognized problems or issues in the life sciences.
- Research designs must include a suitable control group.
- Experiments should address themselves to the development of space research technology, especially for those laboratory techniques which are compromised on earth by gravitational effects (e. g., sedimentation and thermal convection).

## ROLE OF NASA IN EXPERIMENT PLANNING AND DEVELOPMENT

- ENGINEERING ASSISTANCE IN EXPERIMENT PLANNING
- GUIDANCE IN EQUIPMENT DEVELOPMENT (CORE)
- EXPERIMENT INTEGRATION
- SIMULATION PROGRAMS AND TESTS
- DETAILED MISSION PLANNING
- EXPERIMENTER/PAYLOAD SPECIALIST/MISSION SPECIALISTS ORIENTATION AND TRAINING
- INFLIGHT SUPPORT FOR EXPERIMENTS THROUGH THE PAYLOAD OPERATIONS CONTROL CENTER (POCC)
- \* EXPERIMENTER WILL BE RELIEVED INSOFAR AS POSSIBLE FROM NON-SCIENCE ASPECTS OF EXPERIMENT PLANNING AND DEVELOPMENT

# STS-Life Sciences Laboratory Operational Flow

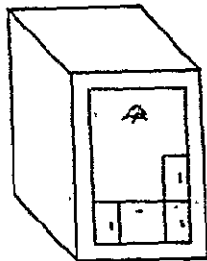




Program Phase	Experimenter Activity	Major Life Sciences Project Interface*
① Experiment solicitation****	Prepare and submit proposal	Program Office Issuing AO (NASA-HDQ)
② Experiment evaluation and selection	Supply additional data if required	Peer review group/ evaluation team leader (NASA-HDQ and JSC support)
▲ Experiment Contract Award		
③ Payload designing and mission definition	Provide detailed experiment resource requirements	Project Scientist** and Engineer*** (JSC)
④ Experiment development and equipment procurement	Design experiment apparatus utilizing CORE and formulate protocols - define GSE requirements	Project scientist and engineer and JSC safety, R&QA personnel and intercenter review board
⑤ Flight planning and training	Provide operational requirements, procedures and data requirements, train crew and define facility requirements	Engineer and JSC flight operations personnel
⑥ Experiment checkout and integration	Provide software, checkout requirements, procedures, and criteria	Engineer and JSC data systems personnel
⑦ Integrated tests/ simulations	Verify proper data acquisition, coordinate experiment activities	Project scientist, engineer, onboard science crew, personnel all JSC supporting divisions
⑧ Launch site integration and pad operations	Verify end-to-end data acquisition, coordinate specific operations, launch site training	Project scientists, engineer and KSC personnel
⑨ Flight monitoring	Verify proper data acquisition, coordinate experiment activities	Project scientist, engineer, onboard crew, JSC flight operations personnel
⑩ Postflight operations	Postflight data evaluation and reporting	Project scientist and engineer

## Typical Life Sciences Laboratories and Example Research Areas

### 1 EXPERIMENT — SELF-CONTAINED



CARRY-ON LABORATORY

- BLOOD AND URINE
- HEMATOLOGY
- CARDIOVASCULAR
- FLUID AND ELECTROLYTE BALANCE

MASS\*: <90 KG

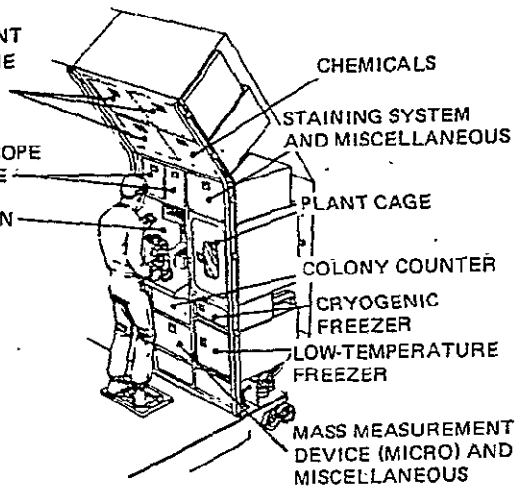
### 4-5 EXPERIMENTS

#### KITS

FLUID MEASUREMENT  
GENERAL DISCIPLINE  
SUPPORT  
OTHERS

MICROSCOPE  
STORAGE

CREW WORK STATION



CHEMICALS

STAINING SYSTEM  
AND MISCELLANEOUS

PLANT CAGE

COLONY COUNTER

CRYOGENIC  
FREEZER

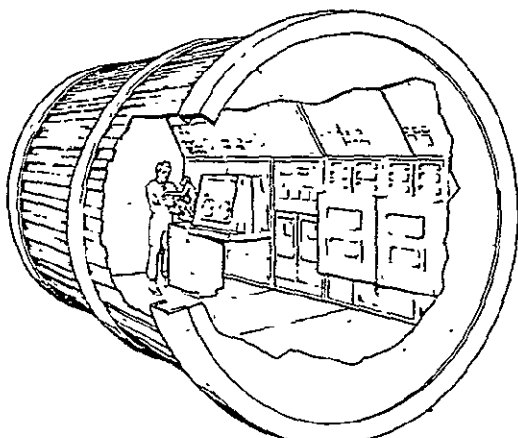
LOW-TEMPERATURE  
FREEZER

MASS MEASUREMENT  
DEVICE (MICRO) AND  
MISCELLANEOUS

- PLANT AND INVERTEBRATE RESEARCH
- PRIMATE RESEARCH
- SMALL VERTEBRATE RESEARCH
- CELLS AND TISSUES RESEARCH
- MAN-SYSTEMS INTEGRATION

MASS\*: 250 TO 900 KG (TYPICAL)

MINILABORATORY



DEDICATED LABORATORY

### 15-20 EXPERIMENTS

- MEDICAL EMPHASIS
- BIOLOGY EMPHASIS
- ALL LIFE SCIENCES DISCIPLINES

MASS\*: 2400 TO 3400 KG (TYPICAL)

\*INCLUDES RACKS AND ALL EXPERIMENT  
RELATED EQUIPMENT

## SUMMARY OF LIFE SCIENCES CAPABILITIES AVAILABLE TO THE EXPERIMENTER

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### General: For all laboratories

Mission Durations	Initially up to 7 days Planned up to 30 days.
Crew Accommodations (in Orbiter)	Living and working space for up to 4 payload specialists; NASA will provide training for payload specialists, (experiment training will be provided by experimenter.)
Habitable Environment	Two gas; 1-atmosphere pressure, 21°C (70°F) nominal temperature
Common Operations Research Equipment (CORE)	Over 100 general-purpose laboratory equipment items are available for life sciences research. Includes: biological specimen holding facilities for wide variety of test specimens; e. g., small primates and vertebrate cells and tissues, and plants.

### Dedicated Spacelab

Resources	All payload resources as defined by Spacelab Payload Accommodation Handbook (ESA SLP/2104) are available for approximately 15 to 20 experiments.
<ul style="list-style-type: none"><li>● Electrical power</li><li>● Heat rejection - air</li><li>● Payload data acquisition<ul style="list-style-type: none"><li>- Housekeeping</li><li>- Scientific</li></ul></li><li>● Data transmission to ground via TDRSS</li><li>● Payload command; data voice</li><li>● Payload data processing and displays; analog, digital, video, computers</li></ul>	Total mass available to payload and mission dependent equipment: up to 6,320 kg (14,060 lb).

### Minilaboratories

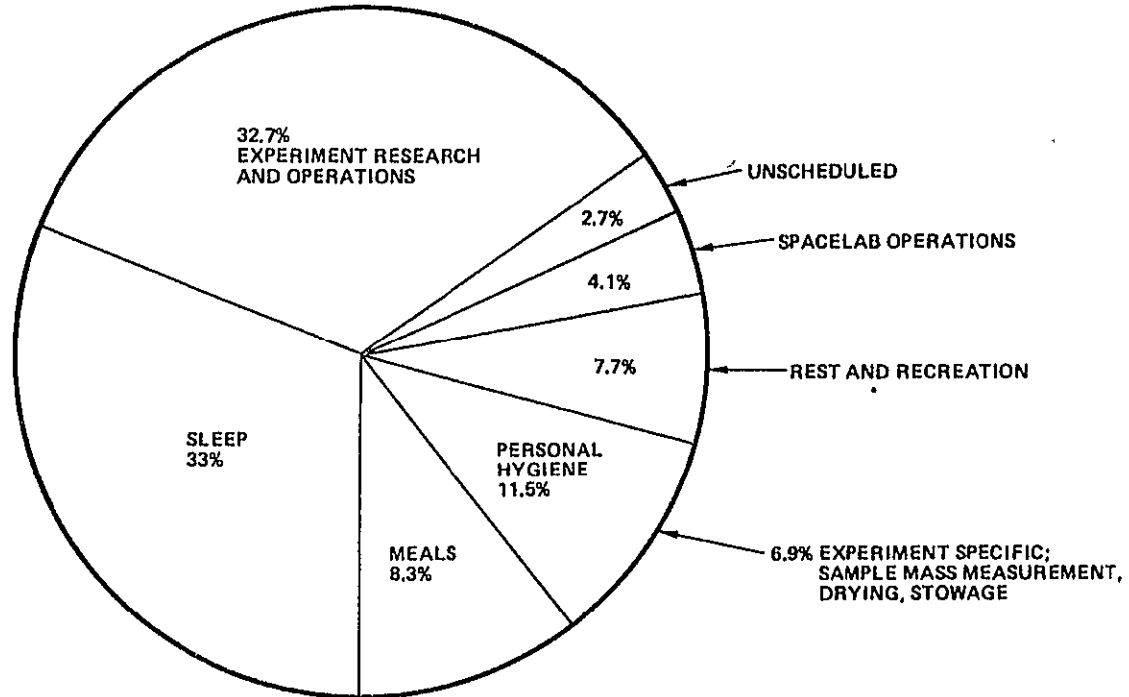
Resources	An allocated portion of that shown above for dedicated: on the order of 20 to 25% for 4 or 5 experiments as a shared flight.
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### Carry-on Laboratories

Resources	Basically they must be self-contained with no resources required: under 91 kg (200 lb) - Note: Certain resources may be available at additional cost.
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**Crew Activity Summary for Typical Life Sciences Dedicated Laboratory**



## LIFE SCIENCES SPACELAB MISSION CONFIGURATION

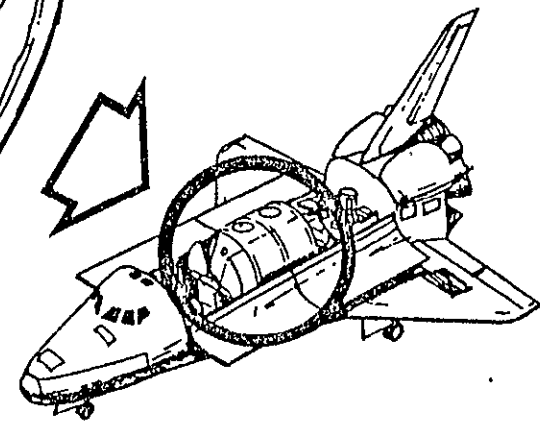
Surgical Workbench

- Environmental Control
- Specimen Nutrition
- Waste Management
- Data Management
- Experimental Function

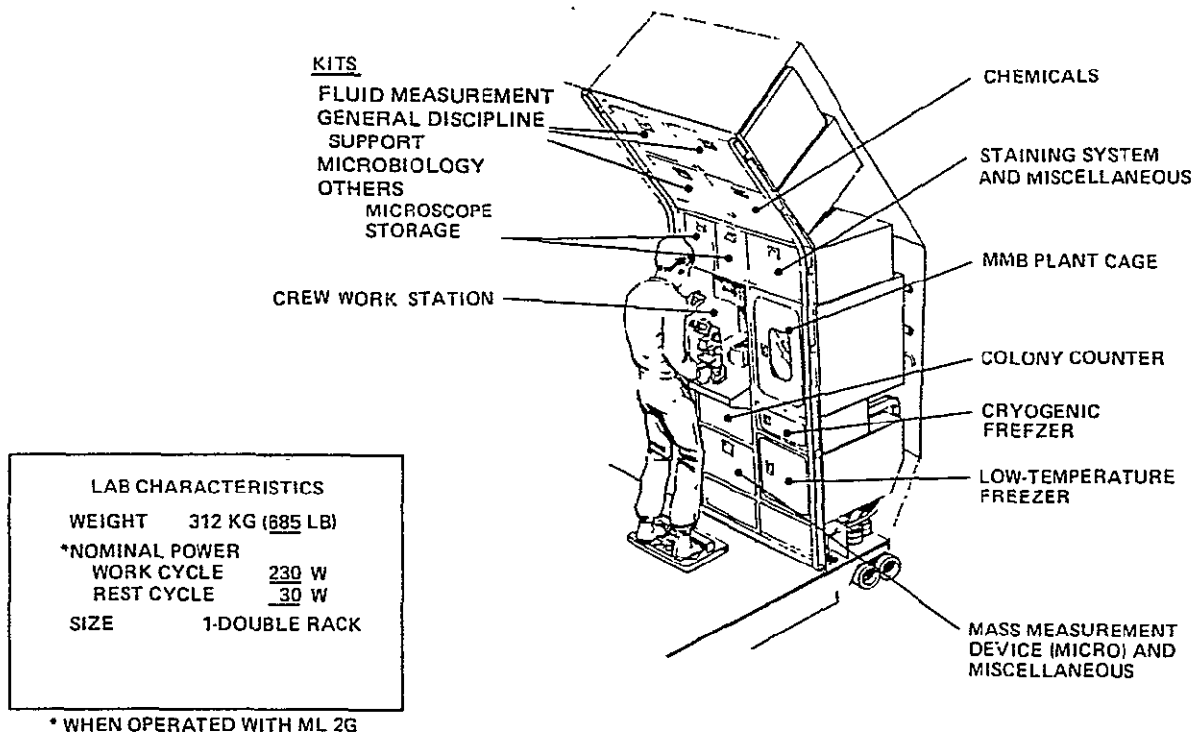
Rodent Holding Unit

Primate Holding Unit

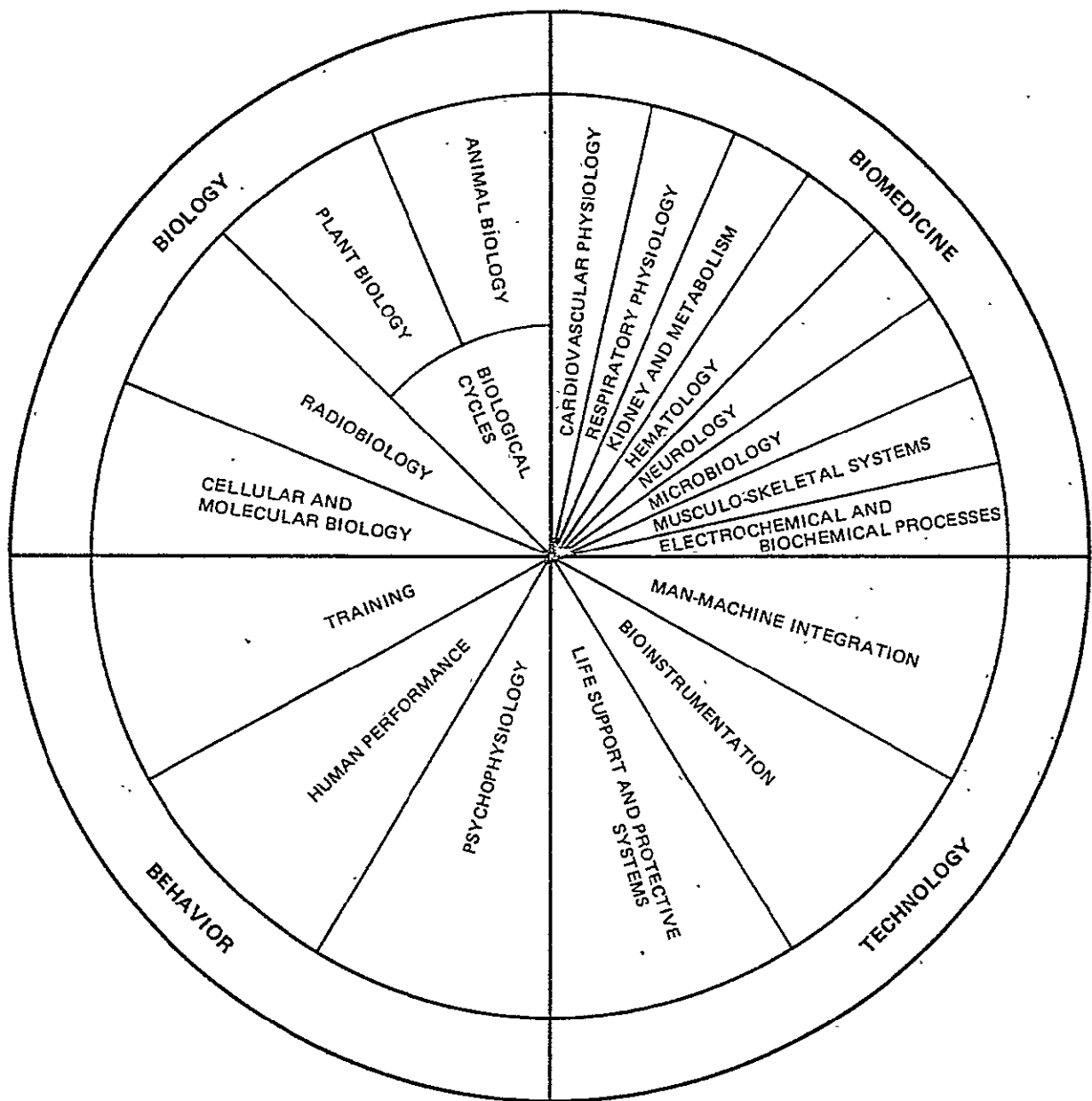
Plant Holding Unit



## Biological Specimen Examination and Experimentation



- Specimen gross and microscopic examination
- Detailed photography of specimen characteristics
- Specimen weight and dimensional measurements
- General specimen manipulators
- Specimen dissection and preparation for postflight analysis.



Life Sciences Discipline Areas

## BIOLOGICAL CYCLES

- VIRTUALLY NOTHING IS KNOWN OF THE RESPONSE TO EXTENDED FLIGHT OF THE PERIODICITY OF THE MANY BASIC BIOLOGICAL RHYTHMS.

## BOTANY

- STUDIES PROPOSED ON THE INFLUENCE OF GRAVITY ON THE GEOTROPIC RESPONSE.
- FINDINGS OF CHROMOSOME ABERRATIONS AND MITOTIC ABNORMALITIES DURING SPACEFLIGHT RAISE QUESTIONS AS TO WHETHER PLANTS CAN GROW AND DEVELOP NORMALLY FOR SEVERAL GENERATIONS IN SPACE.

## CARDIOVASCULAR SYSTEM

- A DISPLACEMENT OF BLOOD VOLUME AND OTHER FLUID FROM THE LOWER TO THE UPPER BODY OCCURS IN RESPONSE TO WEIGHTLESSNESS
- DECONDITIONING OF THE CARDIOVASCULAR SYSTEM ENSUES
- INFLIGHT EXERCISE MAY TEMPORARILY ALLEVIATE THE SITUATION
- UPON RETURN TO EARTH, A DECREASED ORTHOSTATIC TOLERANCE OF THE CARDIOVASCULAR SYSTEM TO ONE-GRAVITY BURDEN HAS BEEN NOTED
- CARDIAC PERFORMANCE
  - NO DECREMENT NOTED DURING IN-FLIGHT EXERCISE
  - DEGRADED RESPONSE NOTED DURING LBNP
    - MANIFESTED AS ELEVATED HEART RATE COMPARED TO PREFLIGHT
    - SEVERAL INDIVIDUALS CLOSE TO FAINTING BECAUSE OF TEMPORARY SUSPENSION OF BLOOD CIRCULATION TO BRAIN
    - ABNORMALITIES PERSISTED BUT DID NOT APPEAR TO PROGRESS WITH DURATION OF FLIGHT
- POSTFLIGHT
  - DECREASED HEART SIZE
  - LOWER TOLERANCE TO EXERCISE
  - LONG RECOVERY INTERVALS TO NORMAL HEART FUNCTION (30 DAYS)

## CELLULAR AND MOLECULAR BIOLOGY

- U.S. AND SOVIET STUDIES HAVE INDICATED A SLIGHT INCREASE IN CHROMOSOME ABERRATIONS AND MITOTIC ABNORMALITIES IN RESPONSE TO SPACEFLIGHT.
- IF SUBSTANTIATED, FINDINGS MAY BE IMPORTANT IN UNDERSTANDING THE MECHANISM OF CELL PROLIFERATION.



## HEMATOLOGY

- DECREASE IN CIRCULATING RED BLOOD CELLS (APPROXIMATELY 15% AFTER 4 WEEKS'S EXPOSURE TO WEIGHTLESSNESS).
- NORMAL RATES OF RETICULOCYTOSIS ARE SUPPRESSED FOR VARYING DURATIONS POSTFLIGHT.
- CHANGES IN RED CELL SHAPES HAVE BEEN NOTED.
- SIGNIFICANT CHANGES IN PLASMA VOLUME (SKYLAB).

## MICROBIOLOGY - IMMUNOLOGY

- LITTLE IS KNOWN OF POTENTIAL EFFECTS OF SPACEFLIGHT ON IMMUNITY
- MANY ASTRONAUTS ACQUIRED SOME KIND OF SKIN RASH AND SEVERAL HAVE HAD FURUNCULOSIS (MAY CONSTITUTE SEPARATE EFFECT ON THE IMMUNE SYSTEM)
- INFORMATION INDICATES A DECREASE IN T-LYMPHOCYTE NUMBERS IN PERIPHERAL CIRCULATION

## MUSCULO-SKELETAL

- LOSSES IN MUSCLE MASS AND BONE MINERALS
- DECREASED CALF SIZE AND NEGATIVE NITROGEN BALANCE SUGGEST MUSCULAR DECONDITIONING
- PHOSPHORUS AND CALCIUM LOSS, AS WELL AS DIRECTLY MEASURED MINERAL LOSS IN SELECTED BONES SUGGEST DECONDITIONING
- SLIGHT, BUT SIGNIFICANT LOSS OF CALCIUM CONTINUED THROUGHOUT DURATION OF ALL MISSIONS
- BONE MATRIX LOSS INDICATED BY ELEVATED
  - URINARY HYDROXYPROLINE
  - SERUM PARATHYROID HORMONE
  - BLOOD CALCIUM AND PHOSPHORUS

## NEUROLOGY

- SPACE NAUSEA PERSISTS UP TO ONE WEEK IN O-G.
- SENSITIVITY TO ANGULAR ACCELERATION WITH HEAD MOVEMENTS DISAPPEARS.

## PSYCHOPHYSIOLOGY

- QUALITY OF SLEEP NOT SIGNIFICANTLY ALTERED BY SPACEFLIGHT.
- PSYCHOLOGICAL CONSEQUENCES OF SPACEFLIGHT HAVE NOT BEEN MEASURED -- NOT SUFFICIENT TO SIGNIFICANTLY AFFECT THE FUNCTIONING OF CREWS DURING MISSIONS UP TO 84 DAYS.

## RADIOBIOLOGY

- LITTLE INFORMATION GATHERED ON EFFECTS OF SPACE PECULIAR RADIATIONS ON ORGANISMS
- INTENSITIES OF HIGH-ENERGY PARTICLES IN THE SPACE ENVIRONMENT ARE OF SUFFICIENT MAGNITUDE TO POSE A POSSIBLY SERIOUS HAZARD ON LONG-TERM SPACE MISSIONS

## RESPIRATION

- NO APPARENT REASONS TO EXPECT ANY SIGNIFICANT ALTERATIONS IN
  - CELLULAR RESPIRATION
  - GAS DIFFUSION EXCHANGE
  - CONTROL OF RESPIRATION
  
- ABSENCE OF GRAVITY WILL
  - ALTER MECHANICAL FUNCTION OF THE LUNGS
  - DISTRIBUTION OF PULMONARY BLOOD FLOW

## ZOOLOGY

- ° FEW FLIGHT EXPERIMENTS HAVE BEEN PERFORMED ON ANIMALS.
- ° SPACELAB PROVIDES AN OPPORTUNITY TO PERFORM LIFE-CYCLE STUDIES WHICH MAY PROVIDE IMPORTANT INFORMATION ON THE EFFECTS OF WEIGHTLESSNESS.



APPENDIX II SCIENTISTS IDENTIFIED BY SCIENCE NETWORK METHOD

A. REGULATION OF METABOLIC SYSTEMS FOR SKELETAL AND HEART MUSCLE

1. John Holloszy (8)\*  
Department of Preventative Medicine  
Washington University School of Medicine  
St. Louis, MO  
(314) 454-2467
2. Phillip Gollnick (6)  
Department of Physical Education  
Washington State University  
Pullman, Washington  
(509) 335-3309
3. Charles Tipton (6)  
Department of Physiology and Physical Education  
University of Iowa  
Iowa City, Iowa  
(319) 353-5708  
Connective tissues, alteration of bone with stress.
4. Frank Booth (4)  
University of Texas  
Houston, Texas  
(713) 792-5430  
Rate of protein turnover; immobilization, NASA contract.
5. Kenneth Baldwin (4)  
Department of Physiology  
University of California, Irvine  
Irvine, California  
(714) 833-7192
6. Howard Morgan & James R. Neely (2)  
Hershey Medical Center  
University of Pennsylvania  
Hershey, Pennsylvania  
(717) 534-8521
7. V. Reggie Edgerton (2)  
Department of Kinesiology  
UCLA  
Los Angeles, California  
(213) 825-1910

\* Number of recommendations from interview of 12 scientists.

APPENDIX II SCIENTISTS IDENTIFIED BY SCIENCE NETWORK METHOD

(CONTINUED)

8. R. James Barnard (2)  
Department of Surgery  
UCLA  
Los Angeles, California  
(213) 825-3794
9. Marty Kushmerick  
Department of Physiology  
Harvard Medical School  
(617) 732-1896  
Regulation of metabolism
10. David Costill  
Falls State University  
Indianapolis, Indiana  
(317) 285-1156  
Only group using biopsy procedure.
11. George Cahill  
Harvard Medical School  
Boston, Massachusetts  
(617) 732-5960
12. Alfred L. Goldberg  
Dept. of Physiology  
Harvard Medical School  
Boston, Massachusetts  
(617) 732-1854  
Amino acid and protein turnover.
13. Russel Tom Dowell  
Dept. of Physiology, Health Science Center  
University of Oklahoma  
Oklahoma City, Oklahoma  
(405) 325-4115
14. Robert Fitts  
Department of Biology  
Marquette University  
Milwaukee, Wisconsin  
(414) 224-7250
15. Philip Felig  
Medicine  
Yale  
New Haven, Connecticut  
(203) 436-0139

APPENDIX II SCIENTISTS IDENTIFIED BY SCIENCE NETWORK METHOD

(CONTINUED)

16. Lenord Jefferson  
Department of Physiology  
Penn State University  
Hershey Medical Center  
Hershey, Pennsylvania  
(814) 534-8569  
Senior investigator, protein turnover
17. Earl Homsher  
Department of Physiology  
UCLA  
Los Angeles, California  
(213) 825-6976  
Energetics, work-tension, ATP cost
18. Wilfried Mommaerts  
Department of Physiology  
UCLA  
Los Angeles, California  
(213) 825-6866  
Senior investigator.
19. John R. Williamson  
Biochemistry and Biophysics  
University of Pennsylvania  
Philadelphia, Pennsylvania  
(215) 243-8785  
Control of metabolic pathways in heart and liver
20. William Gonyea  
Department of Cell Biology  
Southwest Medical School  
University of Texas Medical Center  
Dallas, Texas  
(214) 688-2226
21. Neil B. Ruderman  
Diabetes and Metabolism  
University Hospital  
Boston, Massachusetts  
(617) 247-6649  
Skeletal muscle
22. Ronald L. Terjung  
Department of Physiology  
State University of New York  
Upstate Medical Center  
Syracuse, New York  
(315) 473-4413

APPENDIX II SCIENTISTS IDENTIFIED BY SCIENCE NETWORK METHOD

(CONTINUED)

23. Robert Armstrong  
Department of Physiology  
Oral Roberts University  
Tulsa, Oklahoma  
(918) 492-6161, ext. 2321  
Research not at regulatory level

## B. BLOOD RHEOLOGY

### B-1 BLOOD SHEAR - PLATELETS & WB CELLS

1. Dr. David Hellums (1)\*  
School of Engineering  
Rice University  
Houston, Texas (713) 527-8101
2. Dr. Peter D. Richardson (2)  
Center for Biomedical Engineering  
Brown University  
Providence, R.I.  
(401) 863-2685

### RED BLOOD CELLS

3. Dr. R. G. Mason (2)  
Dept. of Pathology  
College of Medicine  
University of So. Florida  
12901 N. 30th Street  
Tampa, Florida 33612  
(813) 974-2745
4. Dr. Terry Blackshear (3)  
School of Engineering  
University of Minnesota  
Minneapolis, Minnesota  
(612) 373-3014
5. Dr. Sutera (1)  
Washington University  
St. Louis, Mo
6. Dr. Evans, Dr. Hochmuth (1)  
Duke University  
Durham, NC
7. Dr. Alfred Copely (3) (not very active, now)  
Lab. of Biorheology  
Polytech. Institute of New York  
Brooklyn, NY
8. Steven Armentrout  
Dept. of Hematology and Oncology  
University of California  
Irvine, CA  
(714) 558-5152

\* Number of recommendations.

## B. BLOOD RHEOLOGY (CONTINUED)

### B-2 MICRO-CIRCULATION AND CIRCULATION

1. Dr. Richard Mostardi and Howard Greene (1) (Chemical Engineering)  
Biology Department  
University of Akron  
Akron, Ohio  
(216) 375-7125
2. Dr. W. M. Phillips (2)  
Aerospace Engineering  
Penn. State University  
State College, PA  
(814) 863-0043
3. Mary Wiedeman, David Mills (2)  
Temple University  
Philadelphia, PA
4. Larry Tolbert, Stanley Berger (1)  
Dept. of Mechanical Engineering  
UC Berkley
5. Y. C. Fung, D. Zwiefach (2)  
U. C. San Diego  
La Jolla, CA  
Fung arranged '78 World Congress in Biorheology  
Zwiefach to arrange '79 World Congress in Biorheology
6. John R. Murphy (original reference)  
University Hospital  
Case Western Reserve  
Cleveland, Ohio  
(216) 444-3137

C. CARDIOPULMONARY MECHANICS AND EXTRAVASCULAR LUNG WATER\*

1. John B. West  
Department of Medicine  
University of California, San Diego  
LaJolla, CA 92037  
(714) 452-4190
2. Jere Mead  
School of Public Health  
Harvard Medical School  
Boston, Massachusetts  
(617) 732-1193
3. John W. Severinghaus  
Anesthesia Research Center  
1386 HSE  
University of California, San Francisco  
San Francisco, California 94122  
(415) 666-1143
4. Norman C. Staub  
Department of Physiology and Cardiovascular Research Institute  
University of California  
San Francisco, California 94122  
(415) 666-1071
5. Richard W. Hyde  
Department of Radiation Biology and Biophysics  
University of Rochester  
Rochester, NY 14642  
(716) 275-2121
6. Marvin A. Sackner  
Mt. Sinai Medical Center  
4300 Alton Road  
Miami Beach, Florida 33140
7. Aubrey E. Taylor, (205) 460-7004  
Department of Physiology  
University of South Alabama  
Mobile, Alabama 36688
8. Kenneth Brigham  
Pulmonary Circulation Center  
Room A5102  
Vanderbilt University  
Medical Center  
Nashville, Tennessee 37232  
(615) 322-3412

\* Science network limited to research believed to be aided by 0-gravity.

C. CARDIOPULMONARY MECHANICS AND EXTRAVASCULAR LUNG WATER\*

9. William C. Woolverton  
Department of Surgery  
Medical Center Clinic  
8333 No. Davis Hy.  
Pensacola, Florida 32504  
(904) 478-4129; ext. 330
10. Eric N. C. Milne  
Department of Radiology  
University of California  
Irvine, California  
(714) 833-5904

\* Science network limited to research believed to be aided by 0-gravity.



D. PROTOPLAST FUSION

- Indra Vasil (3)\*  
Department of Botany  
University of Florida  
Gainesville, Florida 32611  
(904) 392-1175
2. K. N. Kao and Oluf Gamborg (7)  
National Research Council of Canada  
Prairie Regional Laboratory  
Saskatoon, Saskatchewan  
Canada S7N-049  
(306) 343-9541
3. Jack Widholm and Ben Mathews (3)  
Department of Agronomy  
University of Illinois  
Urbana, Illinois 61801  
(217) 333-1279
4. David Evans  
Department of Biological Sciences  
State University of New York  
Binghamton, N.Y.  
(607) 798-2445
5. James F. Shepard  
Chairman, Department of Plant Pathology  
Kansas State University  
Manhattan, Kansas 66506  
(913) 532-6011
- Also: Larry Williams  
Division of Biology
6. Robert Lawrence  
Corporate Research Lab.  
Union Carbide  
Tarrytown, N. Y. 10591  
(914) 345-2438
7. Ken Giles                      Note: Just arriving from Australia.  
Iowa State University  
Cedar Falls, Iowa  
(515) 294-4618

\* Number of recommendations from interview of 8 scientists.

D. PROTOPLAST FUSION (continued)

8. Peter Carlson (2) NOTE: Inactive, thought contributor, popular scientist.  
Department of Crops and Soils  
State University  
East Lansing, Michigan
9. Ron Cook  
Flow Laboratories  
Los Angeles, California  
(213) 674-2700